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(REV. 5-93)

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER
2345/169

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

JC11 Rec'd PCT/PTO SEP 26 2001

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/937579

INTERNATIONAL APPLICATION NO.
PCT/EP00/02479

INTERNATIONAL FILING DATE
21 March 2000
(21.03.00)

PRIORITY DATE CLAIMED:
26 March 1999
(26.03.99)

TITLE
METHOD USING PHOTONIC CRYSTALS FOR THE DISPERSION COMPENSATION OF OPTICAL SIGNALS OF DIFFERENT WAVELENGTHS WHICH ARE TRANSMITTED TOGETHER

APPLICANT(S) FOR DO/EO/US

Walter HEITMANN; Hans W. P. KOOPS

Applicant(s) herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (UNSIGNED)
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification and a marked up version of the substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report; International Preliminary Examination Report; and First Page of PCT Publication.

Express Mail No.: EL244507370US

U.S. APPLICATION NO. if known, see 37 CFR 1.5

INTERNATIONAL APPLICATION NO

ATTORNEY'S DOCKET NUMBER

09/937579

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17. ☒ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):

Search Report has been prepared by the EPO or JPO \$860.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) \$690.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$710.00

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$1,000.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) \$100.00

CALCULATIONS | PTO USE ONLY

ENTER APPROPRIATE BASIC FEE AMOUNT =

\$ 860

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).

\$

Claims

Number Filed

Number Extra

Rate

Total Claims

8 - 20 =

0

X \$18.00

\$0

Independent Claims

2 - 3 =

0

X \$80.00

\$0

Multiple dependent claim(s) (if applicable)

+ \$270.00

\$

TOTAL OF ABOVE CALCULATIONS =

\$860

Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).

\$

SUBTOTAL =

\$860

Processing fee of \$130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)).

\$

TOTAL NATIONAL FEE =

\$860

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

\$

TOTAL FEES ENCLOSED =

\$860

Amount to be refunded charged

\$

a. ☐ A check in the amount of \$_____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of \$860.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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NAME

September 26, 2001
DATE

CUSTOMER NO. 26646

By: Linda Study
Linda Study
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[2345/169]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s) : Walter HEITMANN et al.
Serial No. : To Be Assigned
Filed : Herewith
For : METHOD USING PHOTONIC CRYSTALS FOR THE
DISPERSION COMPENSATION OF OPTICAL SIGNALS
OF DIFFERENT WAVELENGTHS WHICH ARE
TRANSMITTED TOGETHER
Art Unit : To Be Assigned
Examiner : To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

SIR:

Please amend without prejudice the above-identified application before
examination, as set forth below.

IN THE TITLE:

Please replace the title with the following:

--METHOD USING PHOTONIC CRYSTALS FOR THE DISPERSION COMPENSATION
OF OPTICAL SIGNALS OF DIFFERENT WAVELENGTHS WHICH ARE
TRANSMITTED TOGETHER--.

IN THE CLAIMS:

Without prejudice, please cancel original claims 1 to 8 in the original application and please cancel substitute claims 1 to 8 from the Revised Pages, and please add new claims 9 to 16 as follows:

9. (New) A method for compensating for the dispersion of co-transmitted optical signals having different wavelengths,

wherein the transmitted optical signals are mutually coupled into an arrangement composed of optically interconnected photonic crystals (K1-Kn), which are positioned one after another on at least one waveguide;

in each photonic crystal, only those signals of one wavelength are reflected or diverted, and the signals of the other wavelengths are transmitted, unattenuated, to the downstream photonic crystal;

it holding for the signals of each wavelength that the path length from the point of in-coupling to the point in the particular photonic crystal (K1-Kn) where they are reflected or deflected, is acted upon by a negative dispersion, which alters or completely cancels the positive dispersion of the coupled-in signals, and the resulting signals of all wavelengths are subsequently further co-transmitted.

10. (New) The method as recited in claim 9,

wherein dispersion differences within the limits preset by the dispersion shifters (NLO1-NLOn) can be compensated for by dispersion shifters (NLO1-NLOn) inserted into the waveguide.

11. (New) An arrangement for compensating for the dispersion of co-transmitted optical signals having different wavelengths,

wherein the arrangement is composed of the successively ordered photonic crystals (K1-Kn), a photonic crystal (K1-Kn) being permanently assigned to each wavelength as a function of its dispersion;

the photonic crystals (K1-Kn) are positioned on at least one common optical waveguide (2);

each photonic crystal (K1-Kn) is tuned to reflect or deflect the signals of one wavelength and to transmit the signals of other wavelengths, unattenuated;

the path length from the point of in-coupling to the point in the particular photonic crystal (K1-Kn) where the signals are reflected or deflected, being acted upon by a negative dispersion, which compensates for the positive dispersion of the coupled-in signals;

and the photonic crystals are optically connected to at least one module which holds ready the reflected or deflected signals of all wavelengths again for further transmission.

12. (New) The dispersion compensation arrangement as recited in claim 11,

wherein the arrangement is composed of at least two photonic crystals (KS1 through KS2) designed as selective reflection filters, disposed one after another on a waveguide (2), the crystals being connected via an optical circulator (1) to the optical fiber input (E) and to the optical fiber output (A),

and the first photonic crystal (KS1) being designed as a reflection filter for the first wavelength (λ_1) and the second photonic crystal (KS2) as a reflection filter for the second wavelength (λ_{1+1}).

13. (New) The arrangement as recited in claim 11,

wherein to simultaneously roughly or finely tune the negative dispersion for various wavelengths, controllable dispersion shifters NLO1 through NLOn of non-linear optical materials are coupled in optically between the photonic crystals (KS1-KSn) designed as selective reflection gratings.

14. (New) The dispersion compensation arrangement as recited in claim 11,

wherein the waveguide (2) is composed of two opposing partial sections, the first partial section being assigned to the optical fiber input (E), and the second partial section being assigned to the optical fiber output (A); and at least two photonic crystals (KD1 and KD2) designed as drop elements are disposed one after another on the first fiber section (2), including outputs for laterally repelling signals of one wavelength; and two photonic components (KA1;KA2) designed as adders are disposed one after another on the second fiber section; each photonic crystal (KD1;KD2) designed as a drop element being optically

connected via its output for laterally repelling, to the oppositely situated input of the photonic crystal (KA1;KA2) designed as an adder.

15. (New) The arrangement as recited in claim 11,

wherein to roughly or finely tune the negative dispersion of each individual wavelength, controllable dispersion shifters NLO1 through NLOn of non-linear optical materials are coupled optically into the optical connections between the laterally disposed outputs of the photonic crystals (KS1-KDn) designed as drop elements and the photonic crystals (KA1-KAn) designed as adders.

16. (New) The arrangement as recited in claim 11,

wherein to simultaneously roughly or finely tune the negative dispersion for various wavelengths, controllable dispersion shifters (NLO1-NLO3) of non-linear optical material are coupled optically into the first waveguide section (2) upstream from the photonic crystals (K3 through K4) designed as drop filters.

REMARKS

This Preliminary Amendment cancels without prejudice original claims 1 to 8 and substitute claims 1 to 8 in the underlying PCT Application No. PCT/EP00/02479, and adds without prejudice new claims 9 to 16. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

The underlying PCT Application No. PCT/EP00/02479 includes an International Search Report, dated July 19, 2000. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT Application No. PCT/EP00/02479 also includes an International Preliminary Examination Report, dated July 30, 2001, and an annex (including substitute claims 1 to 8, associated with the International Preliminary Examination Report). An English translation of the International Preliminary Examination Report and of the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
KENYON & KENYON

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[2345/169]

METHOD FOR COMPENSATING FOR THE DISPERSION OF CO-TRANSMITTED
OPTICAL SIGNALS HAVING DIFFERENT WAVELENGTHS

The present invention is directed to the field of dispersion compensation as applied to co-transmitted optical signals having different wavelengths, in optical communications networks.

5

In optical communications networks set up in known methods heretofore, one installed, almost exclusively, standard single-mode fibers having an attenuation of about 0.4 dB/km and a dispersion minimum at 1310 nm.

To an increasing degree, the wavelength range of around 1550 nm is used for optical communications. This is due to the lower attenuation of approximately 0.2 dB/km, the increasing use of wavelength division-multiplex transmission, and the availability of a virtually perfected optical-fiber light amplifier, the EDFA (erbium doped fiber amplifier), which can be used to amplify several channels simultaneously within a broad range of around 1550 nm.

20 One deficiency of the above approach is that the transmission bandwidth and the amplifier distances are limited by the high dispersion of standard single-mode fibers of about 17 ps/nm x km at 1550 nm. Therefore, for longer transmission routes and bandwidths in the Gb/s range, it is necessary to install
25 dispersion-compensating elements.

It is generally known to use dispersion-compensating fibers (DCF) which exhibit a high negative dispersion. -100ps/nm x km is given as a typical value for the dispersion of a DCF.

30 Accordingly, 17 km of DCF are needed to compensate for the dispersion of a 100 km long standard single-mode fiber. The

compensation fibers are wound onto spools, which must be at least 10 cm in diameter to avoid loss of curvature. There are several drawbacks associated with using a dispersion-compensating fiber DCF for dispersion compensation:

- A substantial length of a relatively expensive, special fiber is needed.
- The fiber spool has large dimensions. This can lead to problems in line repeater stations or in cable jointing chambers, particularly when working with multi-core optical cables.
- A supplementary attenuation is added. Due to their special core structure, dispersion-compensating fibers exhibit an attenuation of about 0.5 dB/km, i.e., a fiber length of 17 km yields an attenuation of about 9dB.

The above described properties and possible applications of dispersion-compensating fibers DCF, as well as the wavelength division-multiplex transmission and optical-fiber light amplifiers are described in detail in "Optische Telekommunikationssysteme" by H. Hultzsich, Damm Publishers, Gelsenkirchen (1996) p. 123 and pp. 296-298.

Another dispersion compensation method is based on the use of optical fiber gratings (see likewise in "Optische Telekommunikationssysteme" by H. Hultzsich, Damm Publishers, Gelsenkirchen (1996) pp. 152 - 153). However, optical fiber gratings of about one meter length are required to compensate for dispersion over broad wavelength ranges, e.g., the EDFA range of 1530 nm - 1570 nm. The manufacturing of very long optical fiber gratings having the necessary tolerances with respect to the grating constants and the requisite long-term stability is expensive and is still in the development stage.

The technical objective of the present invention is directed

to an economical approach that requires little overall space to compensate for the dispersion of co-transmitted optical signals having different wavelengths λ .

5 The achievement of the objective in accordance with the present invention is based on the use of photonic crystals. Photonic crystals are periodic arrays of dielectric materials having high and low dielectric constants, alternately disposed as one-, two-, or three-dimensional gratings having periods of
10 $\lambda/3$ and rod or cubic diameters of $\lambda/6$. See J. D. Joannopoulos et al.: Photonic Crystals: Molding the Flow of Light, ISBN 0-691-03744-2 (1995).

In accordance with the present invention, co-transmitted optical signals of different wavelengths which, after propagating through a line section, exhibit dispersion-induced transit-time differences, are coupled via an optical fiber input E into an arrangement configured as a network, which is made up of photonic crystals K1 through Kn positioned one after another on an optical waveguide 2. Photonic crystals K1 through Kn are, therefore, optically connected to one another. Photonic crystals K1 through Kn are formed in such a way that they reflect or divert signals of a specific wavelength and allow signals having other wavelengths to pass through,
20 unattenuated. For example, the formation of first photonic crystal K1 is such that it exclusively reflects the signals of a first wavelength. Optical signals of other wavelengths pass through photonic crystal K1, unattenuated, and are coupled into the downstream photonic crystal K2. Of those signals transmitted through first photonic crystal K1, the subsequent,
25 second photonic crystal K2 reflects, in turn, only those signals having a second wavelength. It likewise permits the signals having other wavelengths to pass through. In accordance with this principle, the signal continues to be
30 passed on by a photonic crystal to a further photonic crystal until the signals of all wavelengths have been reflected by photonic crystals K1 through Kn assigned to them.

Since the positive dispersion value of the signals coupled into the optical fiber input is known for the individual wavelengths, path lengths, which are afflicted by negative dispersion in the array made up of successively ordered photonic crystals K1 through Kn, are defined in accordance with the individual wavelengths, are dimensionally designed to alter or completely cancel the dispersion differences of the signals of the individual wavelengths. Before the signal of a defined wavelength is reflected in one of the successively ordered photonic crystals K1-Kn, it has already traveled a path length up to the element reflecting the defined wavelength in the photonic crystal and acted upon by such a negative dispersion. This path length is defined by the distance between optical fiber input E and the reflecting mirror in photonic crystal K1 through Kn in question.

The dispersion-compensated signals of different wavelengths reflected by the photonic crystals are again coupled into a shared optical fiber output A to be retransmitted by a suitable module, such as an optical circulator 1.

The method of the present invention shall now be explained in greater detail on the basis of five exemplary embodiments.

Assuming the case where optical signals transmitted with different wavelengths λ_i , e.g., three wavelengths λ_1 , λ_{i+1} , λ_{i+2} , exhibit dispersion-induced transit-time differences after propagating through a line section, the specific embodiments are especially directed to once again compensating for these transit-time differences. However, these approaches also include the option of setting a predistortion including defined transit-time differences for the signals of the individual wavelengths, for example for the wavelengths λ_1 , λ_{i+1} , λ_{i+2} .

Figure 1 depicts an arrangement for compensating for dispersion, where the optical signals afflicted by

transit-time differences are coupled via a shared optical fiber input E into an optical circulator 1. The optical signals afflicted by transit-time differences are coupled by optical circulator 1 into a module made up of photonic crystals KS1 through KSn which are disposed one after another as selective reflection filters on a waveguide 2.

In this context, each of photonic crystals KS1 through KSn is tuned to only reflect the signals having a specific wavelength of those signals coupled in via optical circulator 1, but to allow the signals of the other wavelengths to pass through. It is the actual transit-time difference of the signals of the particular wavelength that determines which photonic crystal KS1 through KSn is designed as a reflection filter for which wavelength. The greater the transit-time difference is, the longer the optical path must also be that the signal needs to travel until complete dispersion compensation is attained.

This path can be precisely calculated. In one exemplary embodiment including, for example, three different wavelengths, this would signify that photonic crystal KS1 only reflects the signals of wavelength λ_1 to optical circulator 1. The light of wavelengths λ_{i+1} , λ_{i+2} is transmitted through photonic crystal KS1, unattenuated, to photonic crystal KS2. Photonic crystal KS2 is tuned to only reflect the signals of wavelength λ_{i+1} . The signals of wavelength λ_{i+2} pass through, unattenuated, to photonic crystal KS3. Photonic crystal KS3 is tuned to only reflect the signals of wavelength λ_{i+2} . Consequently, all signals coupled in via optical circulator 1 are re-reflected to optical circular 1. The now dispersion-compensated signals having the three wavelengths λ_1 , λ_{i+1} , and λ_{i+2} are again coupled by optical circulator 1 into the shared, optical fiber output A, and retransmitted via appropriate downstream devices.

Figure 2 illustrates the transmission as a function of the wavelength for the three photonic crystals KS1-KS3 designed as

selective reflection filters.

The specific embodiment pictured in Figure 3 differs from the approach according to Figure 1 in that tunable dispersion shifters NLO1-NLOn are additionally interposed in waveguides 2 between photonic crystals KS1-KSn designed as selective reflection filters. The tunable dispersion shifters NLO1-NLOn make further dispersion compensation possible in addition to the fixed path distances encumbered by negative dispersion. In this context, dispersion shifters NLO1-NLOn are preferably tuned to enable the sum of fixed and adjustable dispersion shifting to compensate for the dispersion differences among the individual wavelengths.

The dispersion-compensating arrangement reproduced in Figure 4 is directed to a specific embodiment that functions without optical circulator 1. In this example, photonic crystals KD1 through KDn are tuned to deflect signals of a particular wavelength. Photonic crystals KD1 through KDn, which are successively ordered on waveguide 2, are specifically designed as drop filters, which laterally deflect optical signals of a desired wavelength out of waveguide 2 and allow optical signals of other wavelengths to pass through to the downstream photonic crystal. The signals, which are filtered out laterally in dependence upon their wavelength by photonic crystals KD1 through KDn designed as drop filters, are optically transmitted via waveguide sections to photonic crystals KA1 through KAn designed as adders and are mutually coupled again via optical fiber output A to be further transmitted. The described arrangement eliminates the need for optical circulator 1 that is still required in the first exemplary embodiment. The signals of the various wavelengths are again present, without transit-time differences, at the output of photonic crystal KA1 designed as an adder. The dispersion-compensation arrangement pictured in Figure 4, including photonic crystals KD1 through KDn designed as drop filters and photonic crystals KA1 through KAn designed as

adders, is set up to compensate for the dispersion of the signals of the various wavelengths, in accordance with the dispersion to be expected at suitable geometric distances 3. In this instance, the arrangement is set up to include variable transmission (wavelength 1 through wavelength n), which is selected on the basis of the design and the period intervals of waveguides 2. Waveguides 2 are interrupted by regions in which the signals are coupled out of photonic crystals KD1-KDn in dependence upon their wavelength λ_1 , due to the geometry of the three-terminal region, and are coupled again into the corresponding photonic crystals KA1-KAn designed as adders, and are summed. All signals are then coupled again into optical fiber output A. In this manner, the transit-time displacement caused by dispersion is compensated for all signals. It is necessary to manufacture and install specially adapted components for the various paths of the network, as is the case in all dispersion-compensation techniques. A certain standardization can be achieved, for example, also by employing standardized distances between the stations where the dispersion compensation is carried out.

Figure 5 shows an arrangement which essentially corresponds to that of Figure 4. This arrangement is likewise made up of optical fiber input E, of photonic crystals KD1 through KDn designed as drop filters and configured on waveguide 2, of photonic crystals KA1-KAn designed as adders, and of the shared optical fiber output A.

Additionally situated on the optical paths between the deflecting outputs of photonic components KD1 through KDn designed as drop filters and the inputs of the photonic components KA1 through KAn designed as adders are dispersion shifters NL01 through NL0n, whose dispersion-shifting effect is able to be individually tuned for each wavelength before the signal is fed back via photonic crystals KA1 through KAn, designed as adders, into shared optical fiber output A. The desired dispersion is set by applying different voltages at

dispersion shifters NLO1-NLOn or through the action of other physical parameters, such as temperature, magnetic field, etc. In the process, dispersion shifters NLO1-NLOn can be loaded with one or a plurality of voltages and be made of a plurality of nonlinear optical materials. Dispersion shifters NLO1 through NLOn are preferably connected via planar waveguides 4, or also via photonic crystal waveguides, in each case to photonic crystals KA1 through KAn assigned to them as adders. By selecting appropriate materials and rating the voltage for the individual wavelengths, one can roughly or even finely tune the desired additional dispersion. Nonlinear optical elements NLO of this kind make it possible for the set-up according to Figure 5 to be adapted within certain limits to the particular conditions of the application. Thus, an arrangement in accordance with Figure 5 has universal applicability. Non-linear, optical dispersion shifters NLO1-NLOn can be made, for example, of photonic crystal structures which are filled with liquid crystals. Also conceivable is the use of crystal rod or hole structures filled with non-linear, optical polymers. These structure are constructed in an electrical field that is tuned as a function of the required, non-linear optical dispersion shifting. In this context, the specific, optically non-linear dispersion shift is determined as a function of the compensation path length for the individual wavelengths.

If dispersion shifters NLO1 through NLOn are optically inserted between photonic crystals KD1-KDn, formed as drop elements, and photonic crystals KA1 through KAn functioning as adders, then the tuning is carried out separately for each wavelength. Therefore, this arrangement makes it possible to individually adjust the required dispersion shift for each individual wavelength.

Alternatively, in another advantageous specific embodiment in accordance with Figure 6, dispersion shifters NLO1 through NLOn can be positioned in the optical path (waveguide 2)

between the individual photonic crystals KD1-KDn designed as drop filters. In this case, dispersion shifters NL01-NL0n act on different wavelengths simultaneously. The action of dispersion shifters NL01 through NL0n adds up in the process for the various wavelengths from dispersion shifter to dispersion shifter. The signals are fed back again via the waveguides between photonic crystals KD1-KDn designed as drop filters and photonic crystals KA1-KAn designed as adders, which sum up the signals and feed them back again into optical fiber output A.

The approach of the present invention makes it possible to assemble high-quality, photonic-crystal add-drop filters, which are approximately 1000 times shorter than conventional diffraction gratings that are configured as chirped gratings at a length of approximately 100 cm. The approach of the present invention makes it possible to construct a dispersion-compensation arrangement that is accommodated on a chip of a few centimeters in size. This chip component has the advantage of a greater temperature stability, so that it can also be used for larger temperature ranges. In addition, in the specific embodiments according to Figures 4, 5, and 6, the need is eliminated for cost-intensive circulator 2. Besides improving operation, the present invention provides a much more economical approach than one based on the known, conventional structures. The electrically tunable dispersion shifters NL01 through NL0n make it possible to adapt the approach on an individual basis to the particular requirements, even given different path lengths.

Solid-state waveguide technology can be used to implement the practical design of the dispersion-compensation arrangement of the present invention by employing three-dimensional additive lithography or electrolytic, light-supported etching of silicon, including appropriate patterning of the apertured mask.

Table of Reference Numerals

| | | |
|----|-----------|--|
| | E | optical fiber input |
| | A | optical fiber output |
| 5 | 1 | optical circulator |
| | 2 | waveguides |
| | 3 | geometric distances between the photonic crystals |
| | 4 | planar waveguides |
| | K1-Kn | photonic crystals |
| 10 | KS1-KSn | photonic crystals designed as selective reflection filters |
| | KD1-KDn | photonic crystals designed as drop elements |
| | KA1-KAn | photonic crystals designed as adders |
| | NL01-NL04 | dispersion shifters |
| | λ | wavelength |

6-29-2001 EPO BERLIN

(8) What is claimed is:

1. A method for compensating for the dispersion of co-transmitted optical signals having different wavelengths,
wherein the transmitted optical signals are mutually coupled into an arrangement composed of optically interconnected photonic crystals (K1-Kn), which are positioned one after another on at least one waveguide (2);
in each photonic crystal, only those signals of one wavelength are reflected or diverted, and the signals of the other wavelengths are transmitted, unattenuated, to the downstream photonic crystal;
it holding for the signals of each wavelength that the path length from the point of in-coupling to the point in the particular photonic crystal (K1-Kn) where they are reflected or deflected, is acted upon by a negative dispersion, which alters or completely cancels the positive dispersion of the coupled-in signals, and the resulting signals of all wavelengths are subsequently further co-transmitted.
2. The method as recited in Claim 1,
wherein dispersion differences within the limits preset by the dispersion shifters (NLO1-NLOn) can be compensated for by dispersion shifters (NLO1-NLOn) inserted into the waveguide (2).

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3. An arrangement for compensating for the dispersion of co-transmitted optical signals having different wavelengths, wherein the arrangement is composed of the successively ordered photonic crystals (K1-Kn), a photonic crystal (K1-Kn) being permanently assigned to each wavelength as a function of its dispersion; the photonic crystals (K1-Kn) are positioned on at least one common optical waveguide (2); each photonic crystal (K1-Kn) is tuned to reflect or deflect the signals of one wavelength and to transmit the signals of other wavelengths, unattenuated; the path length from the point of in-coupling to the point in the particular photonic crystal (K1-Kn) where the signals are reflected or deflected, being acted upon by a negative dispersion, which compensates for the positive dispersion of the coupled-in signals; and the photonic crystals are optically connected to at least one module which holds ready the reflected or deflected signals of all wavelengths again for further transmission.
4. The dispersion compensation arrangement as recited in Claim 3, wherein the arrangement is composed of at least two photonic crystals (KS1 through KS2) designed as selective reflection filters, disposed one after another on a waveguide (2), the crystals being connected via an optical circulator (1) to the optical fiber input (E) and to the optical fiber output (A), and the first photonic crystal (KS1) being designed as a reflection filter for the first wavelength (λ_1) and the second photonic crystal (KS2) as a reflection filter for the second wavelength (λ_{1+1}).
5. The arrangement as recited in Claims 3 and 4, wherein to simultaneously roughly or finely tune the

negative dispersion for various wavelengths, controllable dispersion shifters NLO1 through NLOn of non-linear optical materials are coupled in optically between the photonic crystals (KS1-KSn) designed as selective reflection gratings.

6. The dispersion compensation arrangement as recited in Claims 3 and 4, wherein the waveguide (2) is composed of two opposing partial sections, the first partial section being assigned to the optical fiber input (E), and the second partial section being assigned to the optical fiber output (A); and at least two photonic crystals (KD1 and KD2) designed as drop elements are disposed one after another on the first fiber section (2), including outputs for laterally repelling signals of one wavelength; and two photonic components (KA1;KA2) designed as adders are disposed one after another on the second fiber section; each photonic crystal (KD1;KD2) designed as a drop element being optically connected via its output for laterally repelling, to the oppositely situated input of the photonic crystal (KA1;KA2) designed as an adder.

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7. The arrangement as recited in Claims 3 and 6, wherein to roughly or finely tune the negative dispersion of each individual wavelength, controllable dispersion shifters NLO1 through NLOn of non-linear optical materials are coupled optically into the optical connections between the laterally disposed outputs of the photonic crystals (KS1-KDn) designed as drop elements and the photonic crystals (KA1-KAn) designed as adders.
8. The arrangement as recited in Claims 3 and 6, wherein to simultaneously roughly or finely tune the negative dispersion for various wavelengths, controllable dispersion shifters (NLO1-NLO3) of non-linear optical material are coupled optically into the first waveguide section (2) upstream from the photonic crystals (K3 through K4) designed as drop filters.

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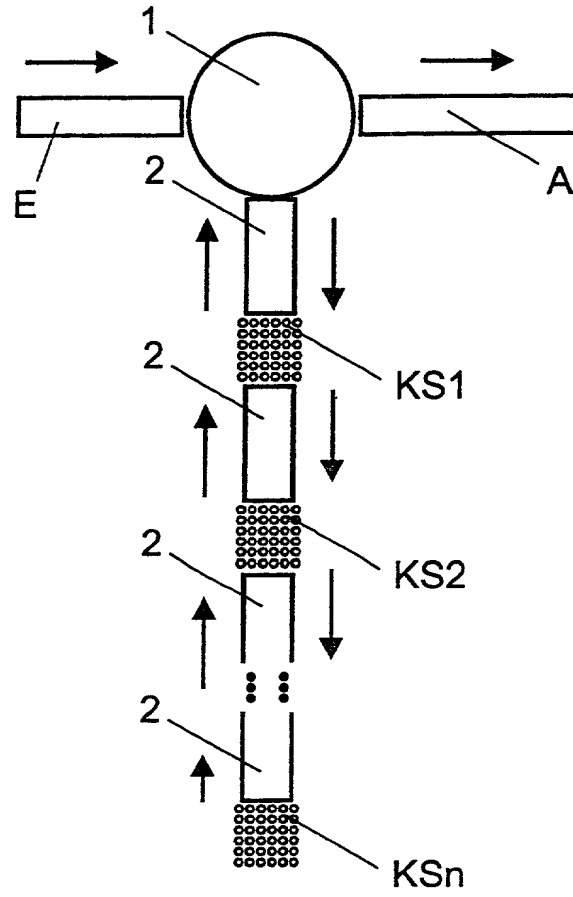


Fig. 1

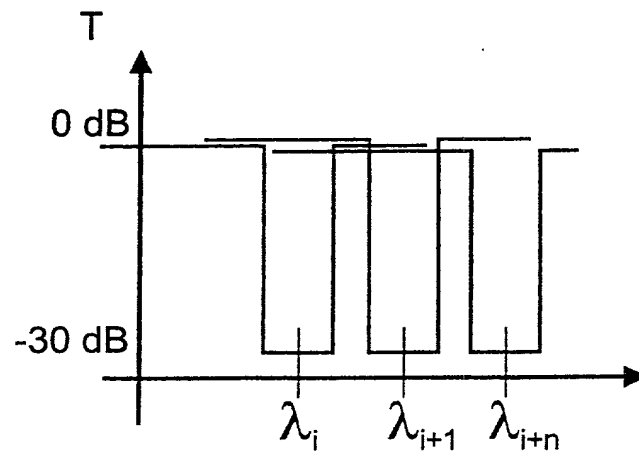


Fig. 2

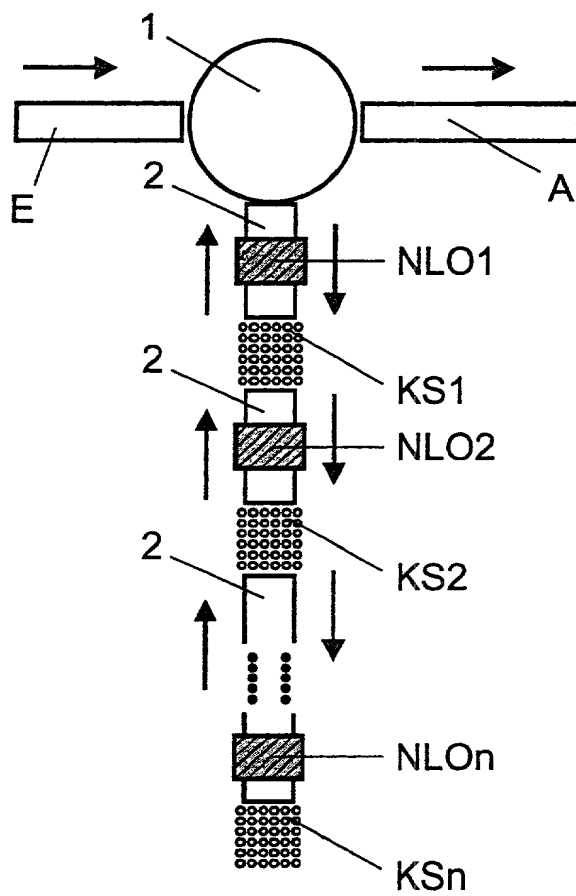


Fig. 3

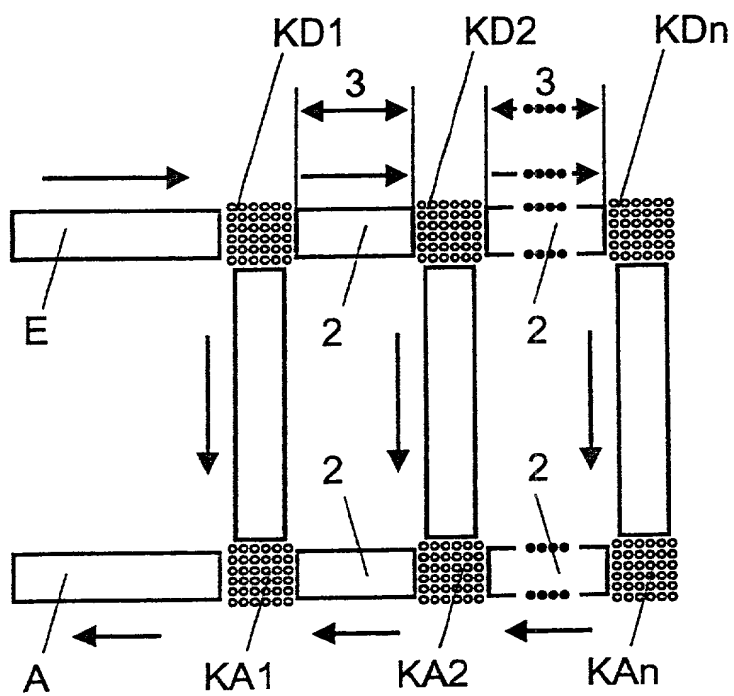


Fig. 4

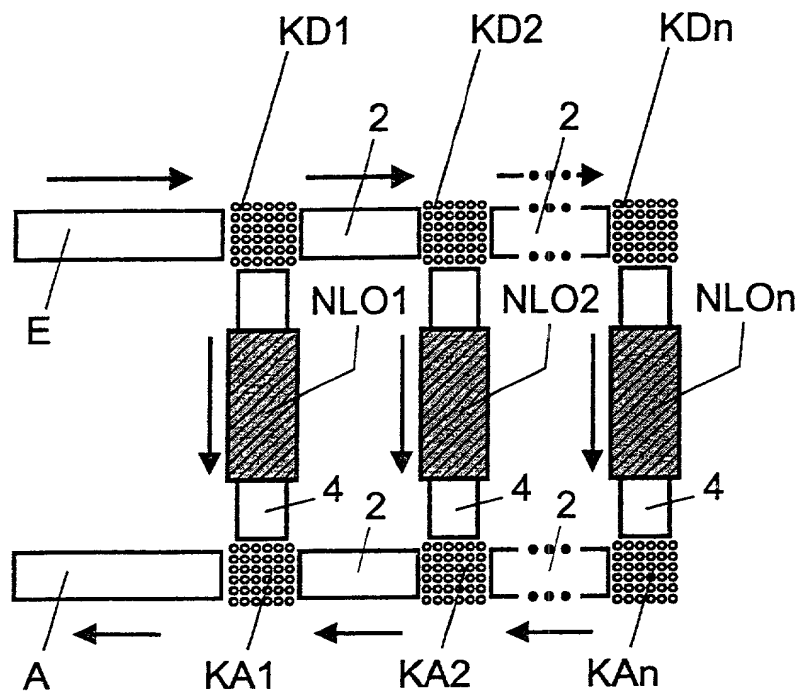


Fig. 5

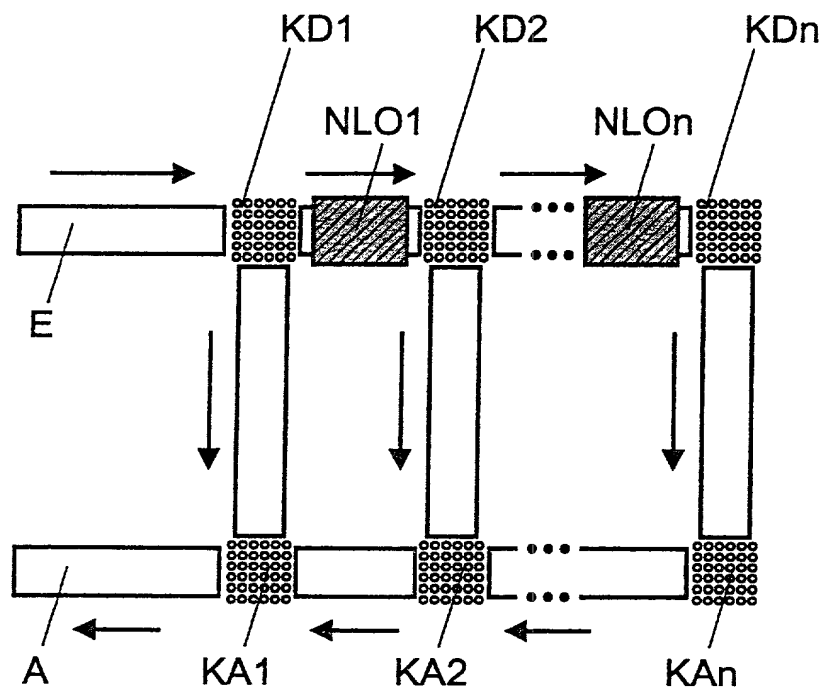


Fig. 6

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD USING PHOTONIC CRYSTALS FOR THE DISPERSION COMPENSATION OF OPTICAL SIGNALS OF DIFFERENT WAVELENGTHS WHICH ARE TRANSMITTED TOGETHER**, the specification of which was filed as International Application No. PCT/EP00/02479 on March 21, 2000 and filed as an application having Serial No. 09/937,579 for Letters Patent in the U.S.P.T.O. on September 26, 2001. ✓

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

| Number | Country Filed | Day/Month/Year | Priority Claimed Under 35 USC 119 |
|----------------|-------------------------|------------------|--------------------------------------|
| 199 15 139.3 ✓ | Fed. Rep. of Germany | March 26, 1999 ✓ | Yes |

3 - And I hereby appoint Richard L. Mayer (Reg. No. 22,490), Gerard A. Messina (Reg. No. 35,952) and Linda M. Shudy (Reg. No. 47,084) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

Please address all communications regarding this application to:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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